User manual CA2CF

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1.   Introduction

1.1 General

The CA2CF is a carrier-frequency measuring amplifier card from Peekel Instruments B.V. It is designed to be used for high-accuracy experimental and industrial measurements and can be used with a variety of Wheatstonebridge-based sensors. This card contains two individual channels, and the card can be used in the SIGNALOG 6000 multi-channel system.
A variety of resistive straingauge configurations can be connected for experimental materials testing. Loadcells can be connected for industrial weighing and force measurements. LVDT's (Linear Variable Differential Transformers) can be used for measuring linear or angular displacements and also Capacitive Transducers can be connected.
The processor card in the SIGNALOG 6000 system controls the settings of each amplifier on the card.

1.2 The Carrier Frequency principle

High-accuracy measuring at the output of passive transducers is usually configured into some sort of a Wheatstone Bridge circuit which always needs some form of reference (bridge supply) voltage.
DC bridge supply is by far the most popular for resistive transducers, but when it comes to the highest sensitivity, DC might introduce different spurious voltages which makes the measuring unreliable. In the late 50's PEEKEL already developed the Carrier Frequency principle for these applications, where an AC voltage is being used for the supply, which eliminates most of these spurious and misleading signals. Furthermore, AC bridge supply can be also used together with capacitive and inductive transducers.
If dynamic signals are being measured, the AC bridge supply voltage will be "modulated" by the measuring signal and by "detecting" this signal, the output signal becomes available.
This way of measuring, through modulation of a carrier frequency with detection in a later step, is similar to the principle of AM radio. Hence, the term "Carrier Frequency" is being used.
The inherent use of isolation transformers assures a complete isolation between the sensor circuit and the rest of the system.

1.3 General design principles

The following drawings only show the basic principles of the electronics, as it is outside the scope of this user's manual to go in full detail.

The Amplifiers
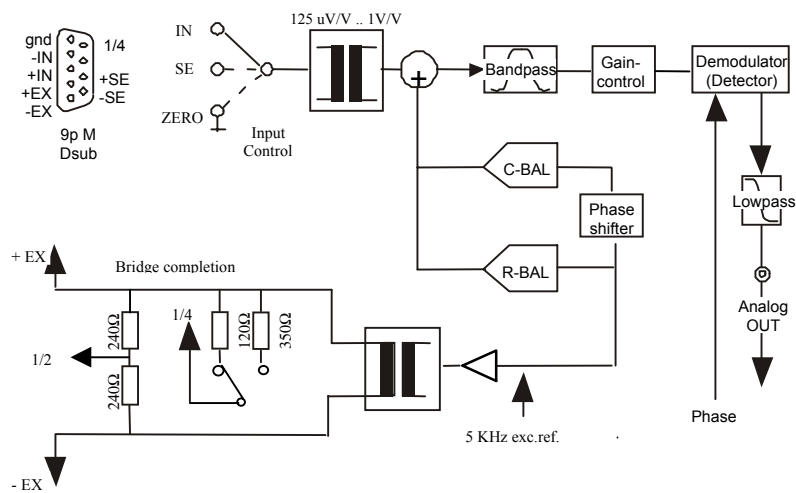
The drawing shows the evident advantage: the two transformers, fully isolating the measuring input from the rest of the system.

2 Signal Connection

At the frontpanel of the card is sub D9 connector for the input of each channel and a coax connector for the output of each channel.

2.1 Inputs

The following pages show examples of the various options of how to **connect** various input signals and transducers to the card. Later in this document, further details are given of how to actually **measure** these signals.

2.1.1 Connecting the Transducers

The carrier-frequency amplifier is mainly used for straingauges and lvdt's. They can be connected in full-, half- or quarter-Wheatstonebridge configurations. The other arms of the bridge can be completed with the internal, on-board, ½- and ¼-bridge complementary-resistors. (These are 240 Ω for 1/2 bridge and 120 Ω or 350 Ω for the 1/4 bridge.)
The precise value for a half-bridge completion is not important as long as these resistors are stable and in balance. The value of a quarter-bridge completion resistor, however, should fairly accurately match the external straingauge, otherwise a too large unbalance (offset) will be the result.
All drawings show lines connecting the **±SE** with the **±EX** lines. These are the **sense-lines** and **must be connected**, even when not 6 but only 4 wires to the straingauge-bridge are used.
The drawings include polarity-signs within the straingauge-resistors. These indicate the polarity of the amplifier-output-signal for increasing strain and increasing resistance.
It is strongly recommended to use shielded cables.

2.1.2 About Cable-capacitance

A topic, inherent with the use of CF-amplifiers (contrary to DC-amplifiers) is cable-capacitance. The capacitance between cables to a straingauge-bridge yields a parasitic impedance parallel to the arms of the Wheatstone bridge. Any unbalance in capacitance may therefore lead to errors in the measured signal.
This becomes crucial in quarter-bridge configurations where the capacitance comes directly across one arm of the bridge.
(Example: every 1 meter cabling of 100 pF/meter, connecting a 120 Ω bridge to a 5 kHz carrier-frequency amplifier, gives rise to 100 μV/V C-signal offset. The carrier-frequency-amplifier, however does suppress this C-signal by at least a factor 1000. This works only if the amplifier is not overloaded by the C-signal. The C-signal therefore should not be more than 4...7 times the selected measurement-range of the amplifier. In the most-sensitive range of 100 μV/V this would allow for 10 meters of cabling.)
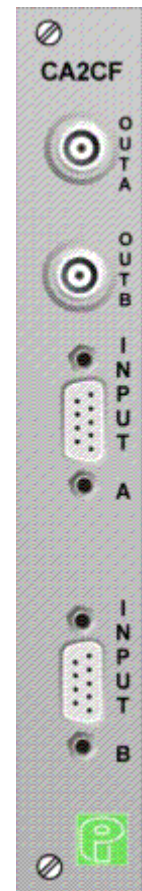
The presence of such a large C-signal is not recommended though. In quarter-bridge configurations therefore it is common practice to compensate the capacitance by a fixed capacitor, built in the other arm (between pins **+EX** and **¼**).

2.1.3 Bridgeconnector pinout

pin 1:   *-EX*   (-excitation)
pin 2:   *+EX*   (+excitation)
pin 3:   *+IN*   (+input)
pin 4:   *-IN*   (-input)
pin 5:   Screen *GND* (ground)
pin 6:   *-SE*   (-sense)
pin 7:   *+SE*   (+sense)
pin 8:   not used, do not connect
pin 9:   *1/4*   (quarter-bridge completion resistor, 120 Ω or 350 Ω)

The straingauge-bridges and lvdt's are connected through 9-pole male DSUB connectors, as seen in the above figure. The abbreviations are as follows:

±EX   Excitation to the transducers. For the carrier-frequency-amplifier this is an AC-signal of 0,5 to 5 volt at normally 5000 Hz. Although the polarity-signs do not have a meaning for this ac-signal, they are used here to indicate the relation with +IN and -IN.

±IN   Differential input of the amplifier. Like for the excitation, the polarity-signs wouldn't have a meaning if they weren't used to indicate the relation with +EX and -EX. Connecting +EX to +IN and -EX to -IN should give a positive (but overload) outputsignal.

±SE   Sense-lines for 6-wire connection of full-bridges. The + SE and - SE connections have to be connected (see diagrams at the next pages) in order to compensate for the voltage drop of the EXcitation voltage over the lines, connected to the measuring sensors.

¼   Quarter-bridge completion resistor. A single external straingauge can be completed by internal resistors in the other bridge-arms, available ¼-pins. The ¼-bridge completion resistor is internally connected to +EX. When also the ½-pin is connected to -IN, a positive strain on the gauge will give a positive-going output voltage from the amplifier. With the settings a choice can be made between a 120 Ω or a 350 Ω internal compensation resistor.

Screen Gnd Screen-ground. At this pin the screen of the cable can be connected. Internally in the Signalog 6000 a selection can be made to connect all the screen grounds to the earth pin of the power inlet, or to connect those pins to an external ground pin.

2.2 Sensor Connections

2.2.1 Full-bridge

Figure 1&2 shows the connection of a full straingauge-bridge. This is the most reliable configuration. The leadwire-resistances affect only the sensitivity of the bridge. For instance 6Ω resistances in both the +EX as well as the -EX wire, connected to a 120Ω bridge, give a decrease in outputsignal of 9.1%. This can be compensated by using the internal sense circuit. However, that does not compensate the temperature-influence on the leadwire-resistance. A temperature-coefficient of 0.4%/°C on 12Ω of copperwire, connected to a 120Ω bridge, will still give 0.04%/°C change in sensitivity. Short, thick cabling is therefore recommended.
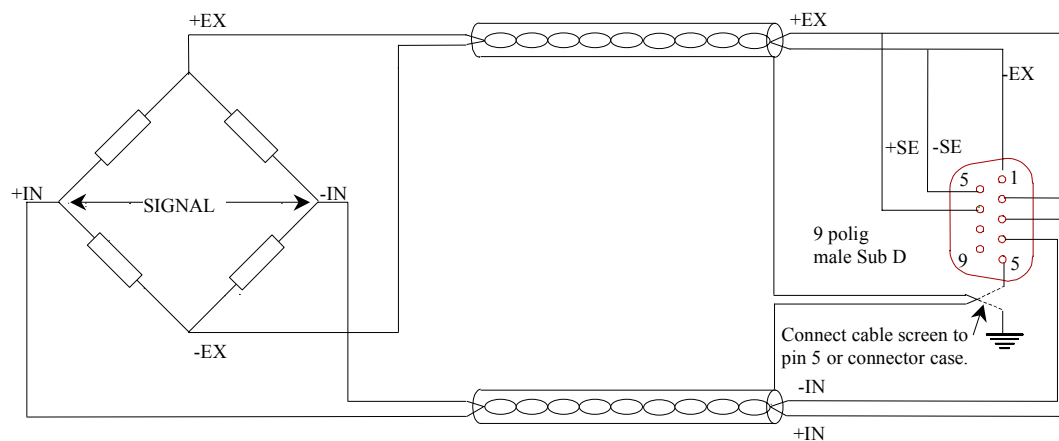

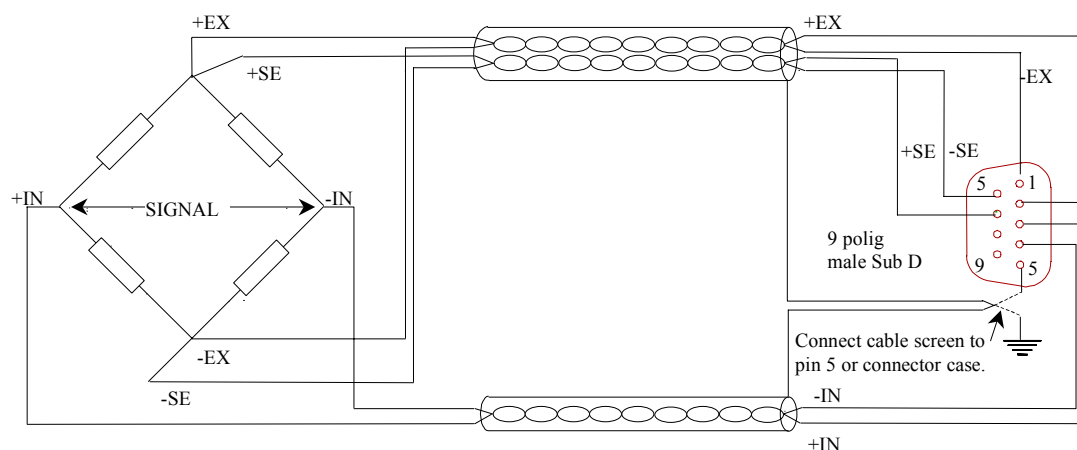**Figure 1**: Full-bridge, **4**-wire, straingauge-connection

Figure 2: Full-bridge, **6**-wire, straingauge-connection

2.2.2 Half-bridge

Figure 3&4 shows half-bridge configured straingauges. The ½-bridge completion-resistors are internally connected to -IN.
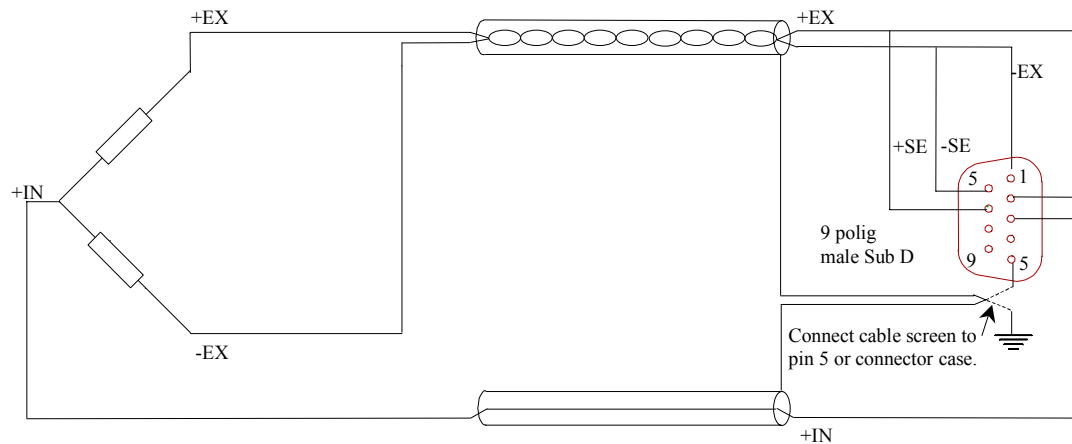
Figure 3: Half bridge, **3**-wire, straingauge-connection
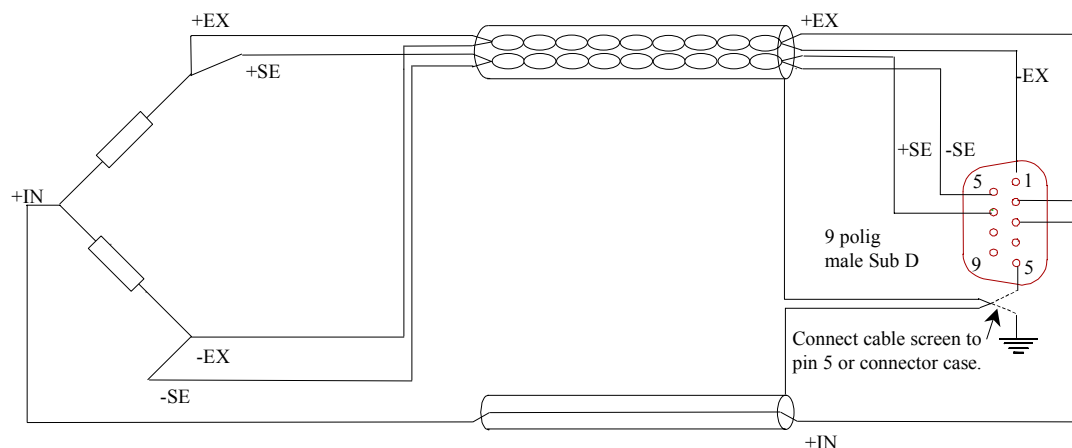
Figure 4: Half bridge, **5**-wire, straingauge-connection

The connection of the ½-bridge completion to -IN sets the amplifier for positive gain: so connecting the +IN signal to +EX gives a positive outputsignal (although in overload). Half-bridge connections are more critical than full-bridge. The leadwire-resistances in the ±EX-lines are in series with the 2 straingauges, in the Wheatstone bridge. Any slight unbalance in these leadwire-resistances will give rise to signal-offset. Every 1mΩ difference in resistance on a 120Ω bridge gives 2 µV/V offset. This may be compensated by use of the internal balance circuit. However, temperature-influence can not be compensated. Short, thick cabling is highly recommended

2.2.3 Quarter-bridge using 2-wires

Application of quarter-bridges is the simplest but least accurate way of measuring. The leadwires in 2-wire configurations are completely incorporated in one arm of the straingauge-bridge. Every 1 mΩ of cabling-resistance in series with a 120Ω straingauge, will already add 2 µV/V signal-offset, though in practical situations it is more likely to meet several ohm's of resistance.
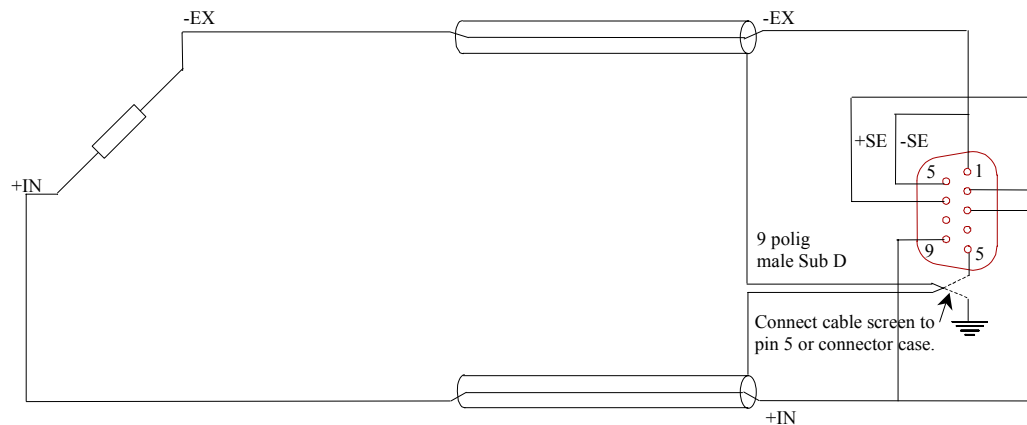
Figure 5: Quarter-bridge, **2**-wire, straingauge-connection

The balance-compensation range is 65 mV/V at 5 volt excitation. This allows for 1.25Ω total leadwire-resistance in series with a 120Ω straingauge. A bridge-voltage of 0.5 volt however gives a 10 times balance-range and enables 12.5Ω leadwire in series with a 120Ω straingauge.
The temperature-influence on the cable-resistance cannot be compensated. The temperature- coefficient of copper of 0.4%/°C will give rise to 8.3 µV/V offset-change for each Ω in series with a 120Ω straingauge. Short and thick cabling is evidently necessary!

2.2.4 Quarter-bridge using 3-wires

Most of the problems, mentioned before, can be avoided by using the 3-wire connection method. It adds the resistance of the -EX-leadwire to the external straingauge, and it adds the resistance of the wire leading to the internal ¼-bridge completion to this internal ¼-bridge resistance. Only the difference in leadwire-resistance (and connector contact-resistance) gives signal-offset.
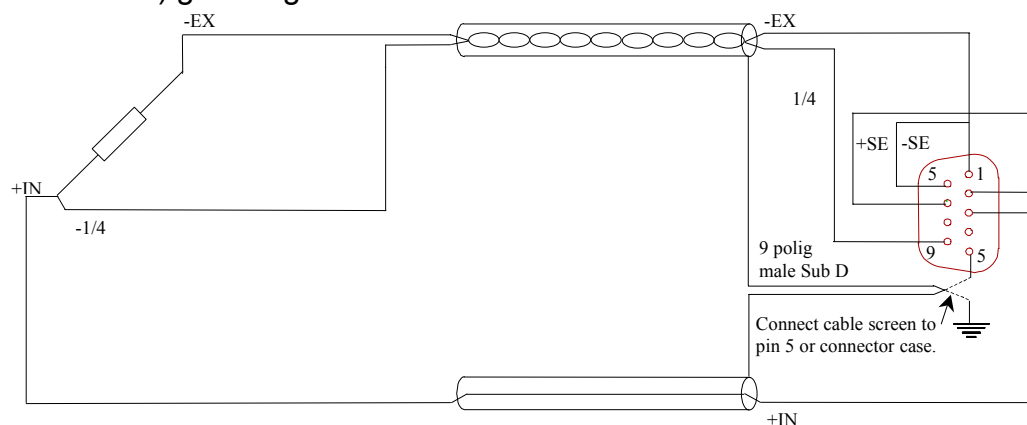
Figure 6: Quarter-bridge, **3**-wire, straingauge-connection.

A situation, similar to the ½-bridge connection method has appeared. Every 1 mΩ of difference in resistance, when using 120Ω straingauges, gives a change in signal-offset of 2 µV/V. This may be compensated internally by the balance circuit. However, the temperature-influence can not be compensated for. Short and thick cabling is again highly recommended.

2.2.5 Displacement Transducers

LVDT's, or *Linear-Variable-Differential Transformers* may be configured as full- or half-bridges. The connection method for both possibilities is shown in the next figures.
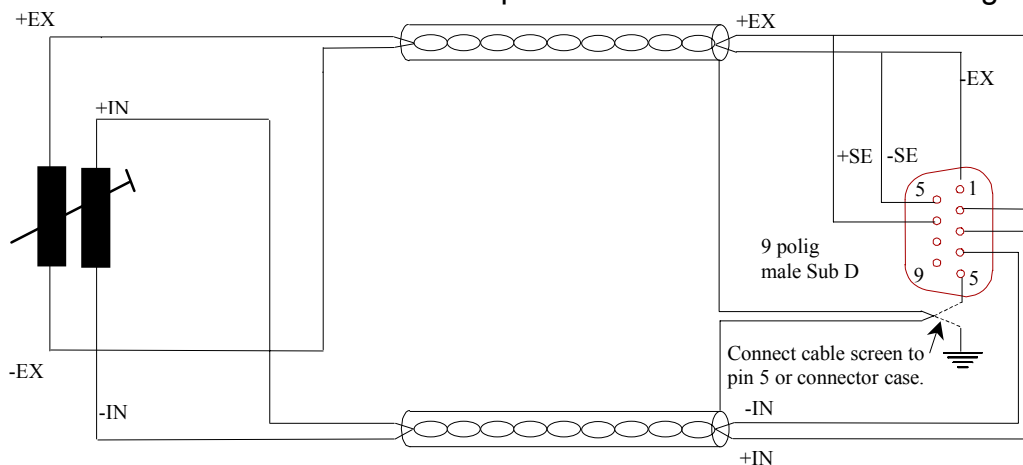
Figure 7: Connection of a full-bridge lvdt.
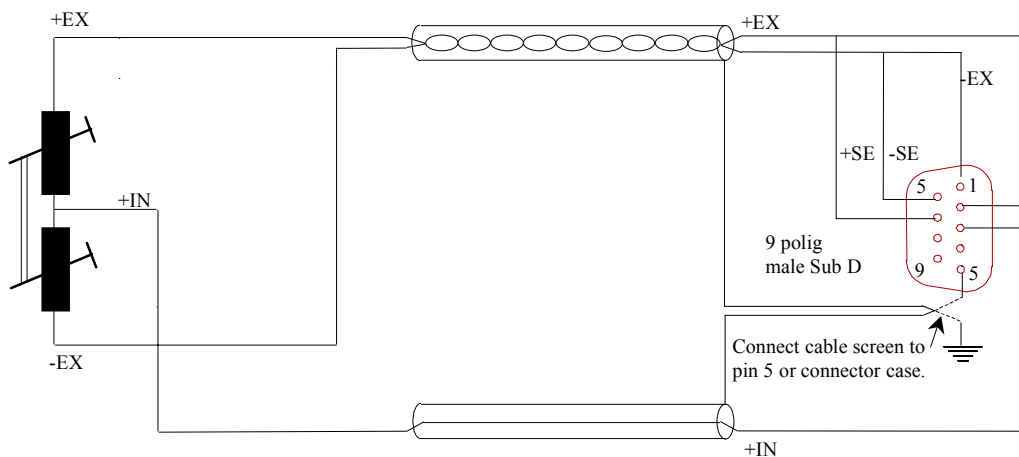
Figure 8: Connection of a half-bridge lvdt

2.3 Outputs

2.3.1 Individual analog output

For each of the 2 amplifiers, the output voltage (0... +/-10 V) is available on the 2 BNC connectors at the front panel of the card.

3 Channel Settings

3.1 General

The CA2CF card is controlled by the processor card. This can be the PB6000 card. The cards are connected to each other through the backplane. When the settings of a CA2CF channel must be changed, this can be done by using the Active X Control.
The different settings shall now be explained using the property windows, which are displayed by the Active X Control.

3.1.1 Presentation of numbers

Throughout the channel-settings, floating-point numbers are used. They are internally stored as 4 bytes and can take very small and very large values. They are generally shown in the format +1.2345 or +12.345 or +123.45 where the plus sign might be replaced by the minus sign. As an example, values smaller than 1.00 will be shown as +123.45 m, where *m* stands for milli or 1/1000.
Also remember that +123.45mV (for example) is the same as +0.12345V.
The *m* can be understood as a prefix to the physical unit (*V* in this case) but can also be thought of as a suffix to the value (+123.45 in this case).
The Active X Control always presents its floating-point numbers using the number suffixes *p*, *n*, *u*, *m*, none, *k*, *M*, *G* and *T, standing for: pico*, *nano*, *micro*, *milli*, none, *kilo*, *Mega*, *Giga* and *Tera*.
A value of +825.0 uV/V is (for example) the same as +0.825 mV/V. On the other side, values larger than 999.99 will be shown for example as 1.2345 k where *k* stands for kilo or 1000.

3.2 Channel pages

The channel pages are displayed on the screen of the PC, when the properties of the Active X control are displayed. On the top of the property box, a TAB is present for each page. Clicking on the desired TAB, will display that page.

3.2.1 General page
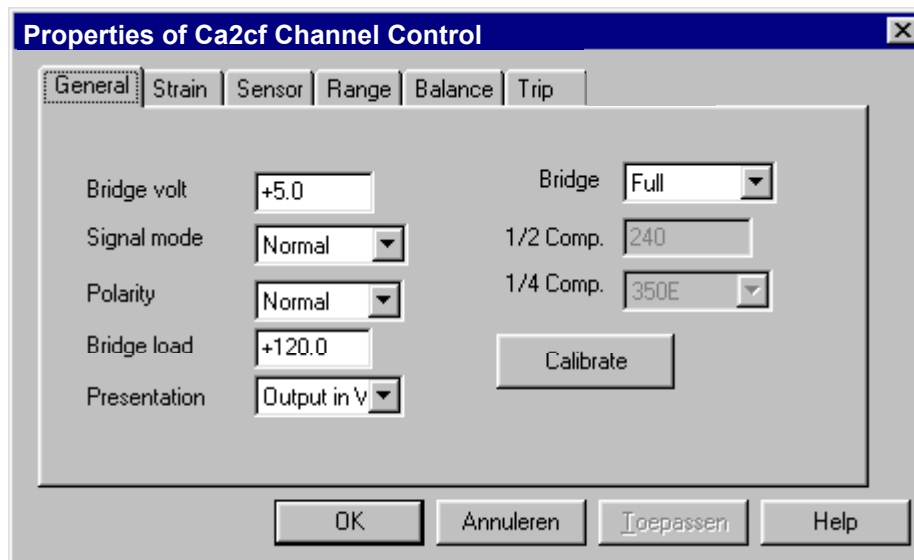
Controls and Functions

Bridge-Volt	*adjustable*	(0.5 ....5 volts)
Signal Mode	*selectable*	(Normal / Capacitive)
Polarity	*selectable*	(Normal / Inverted
Bridge Load	*adjustable*	(60.0 >>> 3000 Ohms)
Output	*selectable*	Default/Vout/Vin/Phys
Bridge	*selectable*	Full/Half/Quarter
½ Comp	*fixed*	always 240Ω
¼ Comp.	*Selectable*	120Ω/350Ω
Calibration	*<execute>*	

Functional Description

The first line ***bridge-volt*** defines the excitation-voltage of the transducer or straingauges. Values from 0.5 … 5 volt are possible. There is a 10% margin to compensate cable-losses when using 6-wire connections (sensing). This allows for (e.g.) 12 Ω total cable-resistance when using 120 Ω straingauges at 5 volt excitation.

When the value for *bridge-volt* is changed, the amplifier will automatically perform a calibration. It measures the real bridge-voltage using the sense-lines and corrects any deviation. It is therefore necessary that the sense-lines are connected on the bridge-connector. *When sensing is not used to compensate cable-losses, it is still necessary to connect the sense-lines on the connector itself.*

This calibration can also be done later with the ***calibration***-command button. It is even necessary when another sensor or straingauges with different resistance is connected to the amplifier.

→ *Notice that the output voltage of the amplifier will be disturbed during the calibration. Null and full-scale reference-measurements are done and will be visible in the amplifier output signal.*

The ***polarity*** parameter gives an easy method of changing the polarity of the output voltage without changing the wiring. But use *normal* if you do not need inverted polarity.

Inverted polarity is the same as a negative gain. When such a negative gain is entered, the polarity will be on inverted mode.

The **signal-mode** is usually set to **normal**. In **capacitive** mode, the amplifier does not measure the normal resistive signal from the straingauges but the capacitive, phase-shifted, signal caused by cable-capacitance and other parasitic causes. Although the amplifier is designed to distinguish between the desired measurement and error-signals, when this signal is large (full-scale or more) it can affect the accuracy of the normal measurement. Capacitive unbalance is mostly observed in quarter-bridge configurations with several meters of cabling.

The **Bridge Load** is standard set to 120Ω. However a different value can be entered. The value entered here must be the impedance seen from the input of the amplifier. When using full bridges, this is the value of one element of the bridge. This value gets more important, when the bridge impedance is increasing. It is used to compensate the measured value with the internal impedance of the amplifier

The **Output** setting will influence the measured value which the control will deliver to the main application. When this value is set at *default* the setting of the processor card will be used. When set to *Vout*, the output voltages will be delivered. Setting it to *Vin* will result in a measurement value of the input voltage. Choosing *Phys* the calculated physical value of the measurement will be delivered.

The **Bridge** setting will activate the internal bridge complementation. A selection can be made from *Full/Half or Quarter* complementation. When *Full* is selected, no complementation is active.

Selecting *half or quarter*, will activate the half bridge complementation. The negative input signal is switch off from the input connector, and connected to the half bridge complementation.

When selecting the *quarter* bridge complementation, a selection can be made for the third resistor between *120Ω* or *350Ω.*

3.2.2 STRAIN page

This page is specifically intended for using with experimental straingauge-measurements. If you measure a complete sensor, like a load-cell or an lvdt, it is easier to use the **SENSOR**-page.

```
Properties of Ca2cf Channel Control                         ⊠

 General │ Strain │ Sensor │ Range │ Balance │ Trip

    K-Factor          +2.0

    Bridge factor     +1.0

    Use E-modules     NO          ▼

    E-Modules         +200.0 k

    E-modules unit    N/mm²


              OK      Annuleren    Toepassen    Help
```

Controls and Functions

K-Factor	*adjustable*	
Bridge-Fact.	*adjustable*	
Use E-Modul	*selectable*	(No / Yes)
E-Modulus	*adjustable*	(- 1.0000.....+ 10 000)
	and *selectable*	(pico…>>>… Tera)
E-Mod unit	*Fixed*	(N/mm²)

Functional Description

The *k-factor* can be read from the datasheet of the manufacturer of the straingauges.
The *bridge-factor* is basically equal to the number of active straingauges in the bridge. If applicable, it can also be used for the correction of Poisson effects in straingauge configurations.
When using half- and quarterbridge configurations, be sure to connect the internal bridge-completion resistors through the bridge-connector. These built-in bridge-completion resistors are: 120 Ω for 1/4 bridge-completion and 2 x 240 Ω for 1/2 bridge-completion (see page 5).
The above parameters allow calculation of the signal into the strain unit *m/m*. If further calculations are to be done to obtain the stress in the material, the *e-modulus* parameters may be set. Set the *use e-modulus* line to *yes* and set the e-modulus-unit and -value as appropriate for the material to be tested.

3.2.3 SENSOR page

This menu specifies the connected sensor like load-cells or lvdt's. If plain straingauges are used, it is easier to use the straingauge-page.
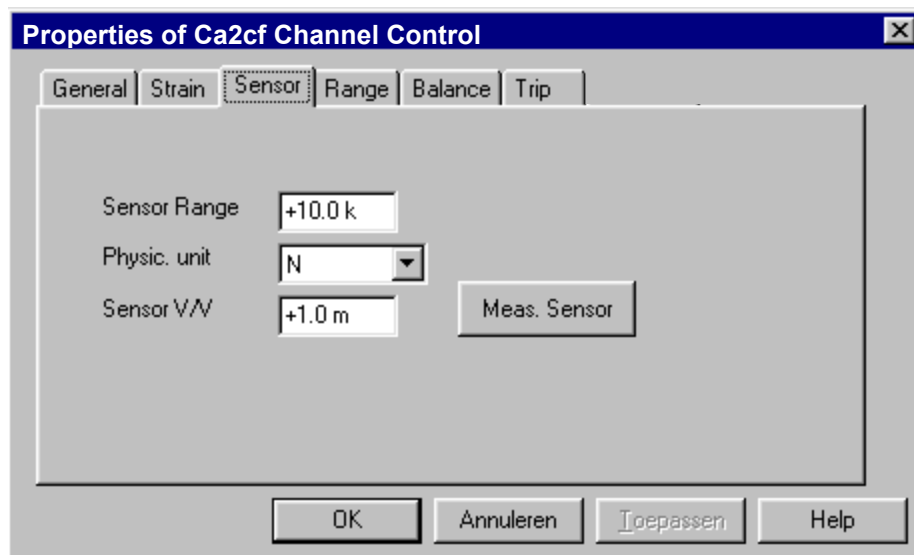
Controls and Functions

Sensor-Range	*adjustable*	(-10,000 . . . >>> . . . +10.000 with
	selectable suffix	(pico /... / Tera)
Physic.Unit	*selectable*	(N, Nm, N/mm^2, Pa, ppm, psi, t, V,
		V/V,%, bar, ^{o}C / g, g/mm^2, G, Hz, inch, K,
		lbs, m, m/m, m/s or m/s^2)
Input [V/V]	*editable*	(00,000 . . . >>> . . 10.000 with
	selectable suffix	(pico /... / Tera)
Measure	*<execute>*	

Functional Description

Sensor-range specifies the physical stimulus (force, displacement) that will generate ***sensor v/v*** at the amplifier-input. In the shown example a load-cell is specified that gives 1 mV/V signal when a force of 10000 Newton is applied. These values can often be read from the datasheet and represent mostly full-load signals. But the values in the sensor-menu can also be obtained from in-house calibration and they do not necessarily have to be full-load signals. If you have measured and know that your 10kN load-cell produces 0.83mV/V as 8.3kN is applied, those values would do the job as well.

The parameter ***physic.unit*** specifies the physical unit of the sensor. A load-cell could have *g* (for gram), *t* or *N* as unit and an lvdt could have *m* (meter, as in centimeter, millimeter) as unit.

The sensor-calibration can automatically be done with the ***measure*** command. If this button is pressed, a measurement is done and the result (in V/V) is placed at the line *input v/v*. If you enter the value for *sensor-range* under which physical condition the measurement was done, you have obtained calibration-values for this sensor.

3.2.4 RANGE page

With this menu the amplifier can be set to a certain measurement-range.

```
Properties of Ca2cf Channel Control                            [X]

 General | Strain | Sensor | Range | Balance | Trip

        Range of    Signal V/V  [▼]

        Range       +1.0 m

        Unit        V/V

        Amplif. Vout +10.0


                    [   OK   ]  [ Annuleren ]  [ Toepassen ]  [  Help  ]
```

Controls and Functions

Range of	*selectable*	(Amplifier / Sensor / Strain)
Range	*adjustable*	(-10.0 .... +10.0)
	and *selectable*	(pico- /... / Tera-)
Unit	*provided by system*	
Amplif. V out	*provided by system*	

Functional Description

The parameter **range of** determines the interpretation of the **range**-parameter. If it is set to *amplifier* the range represents the amplifier-range in V/V. When it is set to *sensor* the range takes into account the values from the sensor-menu and the range is shown with the physical unit from the sensor-menu. If *range of* is set to *strain*, the *range* is calculated using the values in the strain-menu and the physical unit will be m/m, g/mm2 or N/mm2. When the *range of* parameter is changed, the **unit** parameter will change as well. This *unit* can not be modified from within this menu but only in the sensor- and straingauge-menu's.
The *range of* parameter also determines how measurements are shown on the display when the *presentation* parameter in the system menu 5 (after the *set meas* button) is set to *physic. unit*.
The electrical range of the amplifier (when *range of* is set to *amplifier*) can be set between 100uV/V and 1 V/V. Using smaller bridge-voltages than 5 volt has limitations on the smallest value that can be set as the range.
If the **range** is adjusted wrongly, the settings are adjusted to the highest possible gain.

The value for **amplif.Vout** determines the output-voltage when full-scale inputsignals are applied. It is thereby possible to match to data-acquisition equipment that is connected to the amplifier-output.
Most modern systems accept the -10…+10 volt signals that the CA2CF delivers by default.

→ **Note that the full-scale outputvoltage as specified with *amplif.Vout* is not the same as the maximum outputvoltage. Even when 5 volt full-scale is chosen, a maximum of 14 volt may arise on the output during overload-conditions.**

3.2.5 BALANCE page

This menu gives the offset-adjustment of the sensor or straingauges.
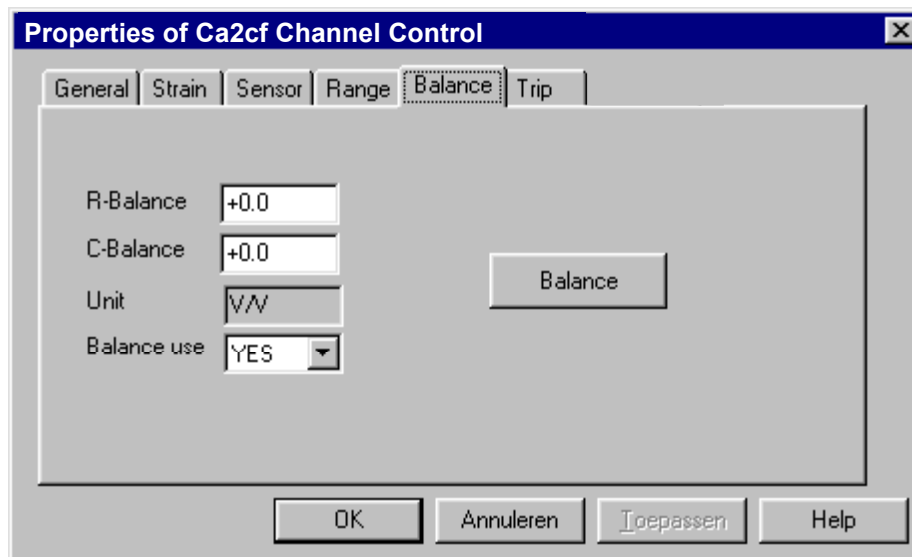
Controls and Functions

Auto-Balance	*\<execute\>*	
R-Balance	*provided by system*	
	or *adjustable*	(-100.0 ... + 100.0)
	and *selectable*	(pico- /... / milli-)
C-Balance	*provided by system*	
	or *adjustable*	(-10.0 ... + 10.0)
	and *selectable*	(pico- /... / milli-)
Unit	*provided by system*	
Use Balance	*selectable*	(Yes / No)

Functional Description

If a sensor or straingauge-bridge is connected with known unbalance, that unbalance-value can be entered as ***...-balance***, in the unit which is presented by the system. That value is then electronically subtracted from the inputsignal in the amplifier.
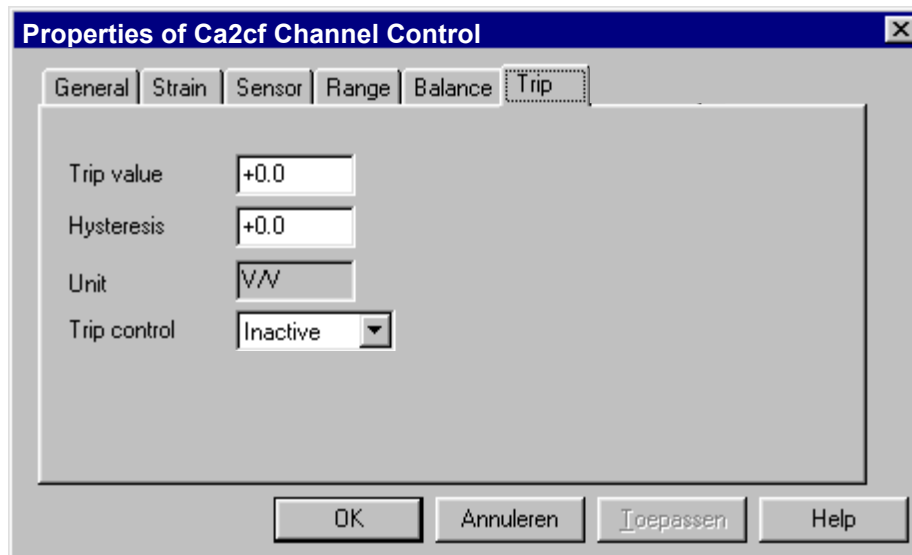
The use of the inputbalance can temporarily be disabled by setting **use balance** to *no*. The value does not change and can be used again by setting *use balance* to *yes* again.

When a sensor or straingauge-bridge with unknown unbalance is connected, it is possible to use the ***auto-balance***-function. When the "Balance" button is pressed, a measurement is done and the result is placed on the *R&C-balance* lines. The output of the amplifier should be near 0 volt. In the larger ranges an outputsignal of a few millivolts may be left.

In the 100uV/V range however a maximum of 50mV may be left at the output because of the 0.5uV/V resolution of the inputbalance.

3.2.6 Trip page

This menu offers the possibility to monitor the measured value and add "trip" -functions to each measurement.

```
Properties of Ca2cf Channel Control                              [X]

 General | Strain | Sensor | Range | Balance | Trip |

   Trip value       +0.0

   Hysteresis       +0.0

   Unit             V/V

   Trip control     Inactive   ▼


              [  OK  ]  [ Annuleren ]  [ Toepassen ]  [ Help ]
```

Controls and Functions

Trip-Value	*editable*	(0000000...999999)
Hysteresis	*editable*	(0000000...999999)
Unit	*provided by system*	
Trip-Control	*selectable*	(unactive / high signal / low signal)

Functional Description

Before setting the trip-levels, all other parameters have to be set. Adjusting Trip-Levels is practically the last adjustment before actual measuring starts.

The ***trip-value*** can be set to any numerical value at which a switching action of the tripping function has to work. This value shall be any level from within the measuring range (see ***range menu).***

Hysteresis can be set as the value at which the trip function goes back to normal again. Normally this is a percentage of the ***trip-value.***

(Example: you wish to get a trip at 98% of the maximum measured value, of, say "100". You then set the Trip-Value at "98". If you now adjust the hysteresis at "3", the trip mechanism will perform a event generated by the Active X Control. The Trip status will switch back to normal when the measured value reaches a value of "98 - 3 = 95".

Unit is automatically displayed according to the measuring range set earlier.

Trip-Control offers the facility of either not tripping at all, tripping at a high level, or tripping at a low level of the measured values.

4 Technical Specifications

General
Suitable for 2-, 3-, 4-,5- or 6-wire connections
Typical accuracy class: 0.1%
    (for bridge loads up to 1000 Ω)
Bandwidth (-3dB): 2000 Hz
Operating temperature: -10°C ... +50 ^{o}C
Permissible cable length: up to 500 m

Bridge supply (transformer-isolated)
Voltage: 0…5 V (adjustable)
Voltage accuracy: +/- 0.05 %
Frequency: 5000 Hz
Frequency accuracy: +/- 1 %
Load: 60…3000 Ω
Internal bridge-completion: ½ -& ¼ bridge

Sensing (6-wire): discontinuous, CPU-controlled, to compensate for voltage drop across cables

Measuring input (transformer-isolated)
Ranges (@5V excitation):
                 +/- 100 μV+/-1 V/V
Input filter: 500 Hz
Maximum Common Mode Voltage: 250 V

Common Mode Rejection (50 Hz): >120 dB

Serial Mode Rejection: >66 dB
Capacitive input overload: max.7x range permissible
Special input filtering for noise reduction

Balance control
R-balance (main): +/- 60 mV/V
C-Balance: @ 120 Ω bridge: up to 10 nF

Output
Full scale voltage: +/- 10 V
Protection: long-term shortcircuit allowed
Maximum capacitive load: 10 nF
Maximum cable length: 100 m (@100 pF/m)

Output Low-pass filter
Frequency (-3 dB): < 2000 Hz
Filter type: 7-stage Butterworth: -42 dB/Octave

Internal bridge completion
240 Ω 1/2-bridge
120 or 350 Ω 1/4 bridge